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Millimeterwave CW Doppler radar for vibration remote sensing

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Abstract : Doppler radar sensors have been heavily utilized at millimeter wavelengths They are currently in use for a variety of applications including commercial and industrial uses in level sensing, motion detection, speed measurement and collision warning sensors. Their relative simplicity and low cost production potential make them attractive for these applications. A millimeter wave Doppler radar development is described in this paper with the off-line DSP techniques to convert the time to frequency conversion from which the velocity of the moving target can be predicted A simple experimental set up has been described where a vibrating metal reed is used as vibrating object. One application area of the 94 GHz Doppler radar for the measurement of rain drop size distribution is highlighted.

Keywords : Doppler radar, moving target indicator (MTI).

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1. Introduction

Doppler radar have been widely employed in aviation for detecting moving targets like an MTI (Moving Target Indicator) Radar. As the Doppler shift of the echo from a moving target is proportional to the operating frequency of radar, attempts have been made to develop Doppler radars at progressively higher and higher frequencies. With the advent of coherent millimeter wave sources, it has now been possible to develop a millimeter wave Doppler radar which would be capable of detecting even the lowest of target velocities like that of a falling raindrops or that of a paratrooper as can be monitored with a ground based Doppler radar. We have studied the feasibility of developing a millimeter wave Doppler radar at 94 GHz with the infrastructure available from two projects. (1) Propagation of millimeter wave by radio links and radiometers and (2) Training Programme in millimeter wave technology. Some of the interesting results obtained are presented in this paper [1].

2. Experimental set up

The block diagram of the experimental set up for a CW Doppler radar developed at 94 GHz is shown in Figure 1. The system essentially consists of a Gunn Phase Locked Oscillator (10 mW) at 94 GHz fed to a standard gain of

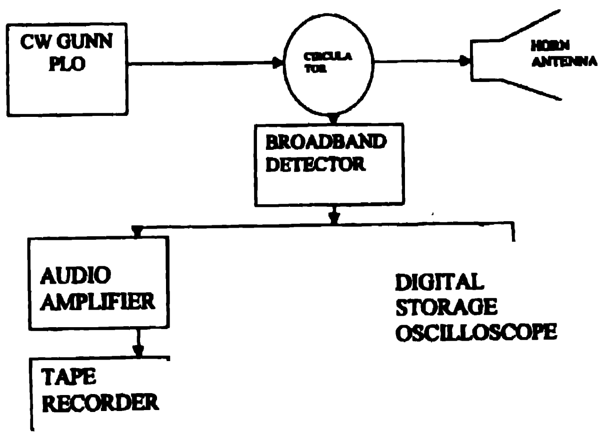

Figure 1. Experimental setup for CW Doppler Radar measurements.

24 dB horn antenna through a circulator. The 3rd port of the circulator is fed to a broad band millimeter wave W-band detector and the detected output fed to (i) a digital storage oscilloscope and (ii) audio amplifier for audio visual monitoring of the beat pattern. This beating effect is produced between the Doppler shifted echo from a moving target

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viewed by the antenna and the 94 GHz signal leaking, back even with the isolation of 20 dB. The audio visual displays are recorded in (i) a tape recorder and (ii) HP 8 pen graphics plotter. The records are then subjected to off-line spectral analysis by the computer.

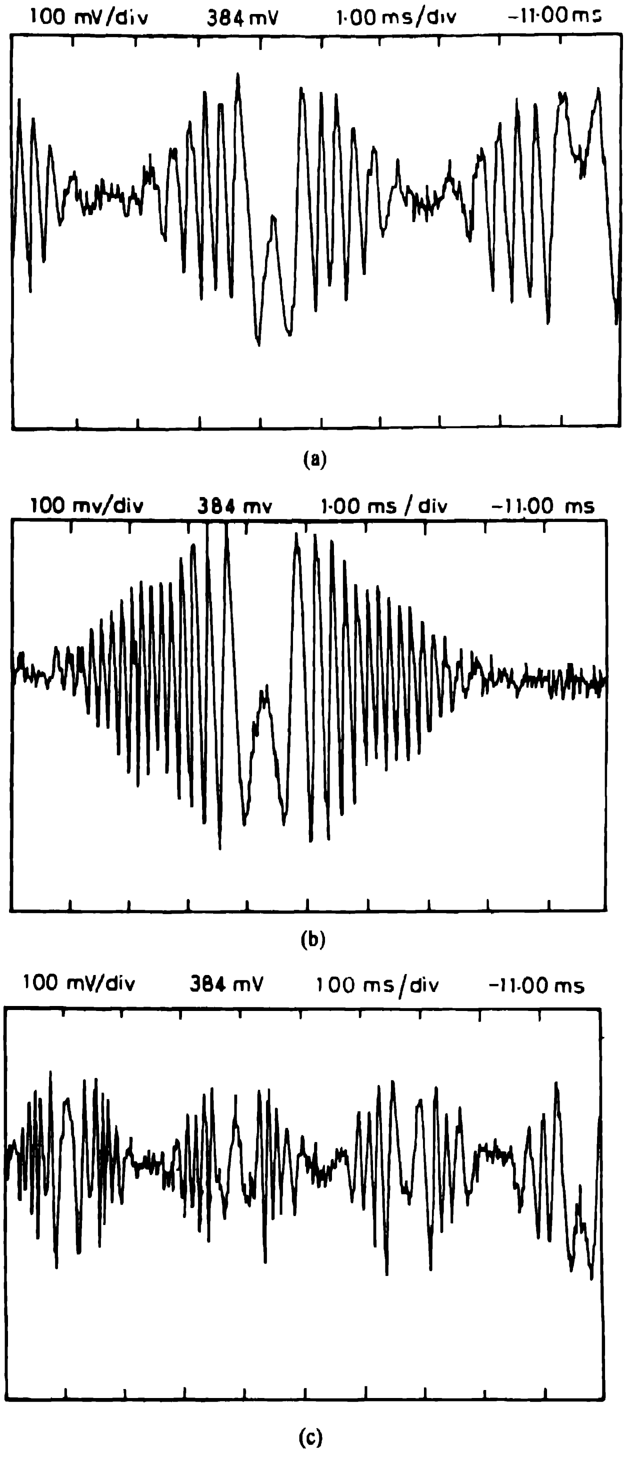

Figure 2. (a) Doppler shift pattern from a vibrating reed, (b) Doppler shifted pattern from the same reed with different vibrational frequency and (c) Doppler pattern of the same reed with different vibrational frequency

3. Measurement of frequency of a vibrating reed by the 94 GHz Doppler radar

A vibrating reed in the form of a flat strip is placed with its plane perpendicular to the antenna beam of the Doppler radar. A sinusoidal Doppler shift pattern is observed as shown in Figures 2(a, b, c). The line of sight velocity of the reed due to vibration would, in fact, vary in sinusoidal fashion at the frequency of vibration with the velocity becoming maximum near the mean position of the vibrating reed. Such envelope modulation is, therefore, an indication of frequency of vibration. Likewise, the modulation of Doppler frequency is also indicative of vibrational frequency of reed.

In view of the above, a direct on line readout of the reed vibration frequency may be obtained by subjecting the Doppler waveform either to (i) envelope detection or (ii) frequency demodulation. Alternatively, the recorded Doppler waveform may be subjected to FFT analysis, off line, by a computer to find out the vibration frequency of the reed.

4. Measurement of rain drop size distribution

Raindrops attenuate microwave and millimeter wave radio signals. If the drop size distribution is known, it is possible to estimate rain attenuation at any frequency from calculation However, the determination of rain drop size is a difficult problem. In fact, conventional instrument like 'distometer' can sense the raindrops near the ground level only where the instrument is installed. A millimeter wave Doppler radar, on the other hand, is capable of making rain drop size measurement for raindrops at various heights from the ground. The developed Doppler radar at 94 GHz has an inclination θ to the vertical. The line of sight velocity of the raindrop will then be $V_r = v \cos \theta$. Operation of the radar with the antenna beam oriented along such a slant path enables us to install the Doppler radar inside an airconditioned hutment.

It may be mentioned here that this technique of measurement of rain drop size can be used as a more precise alternative technique to that possible with a conventional 'distometer'. However, the full capability of the radar can be exploited only if the CW radar is converted to a pulse Doppler radar.

References

[1] *Final report of the project "MWP-Millimeter Wave Propagation" running at the Institute of Radio Physics & Electronics, University of Calcutta, 1992*

[2] *Millitech Millimeter Wave Products Catalogue* p10 (1995)